Rendering Solar and Plasma Dynamic and Evolutionary Process

Project Number: 96-26

Investigator: G.A. Gary/ES82

Purpose

The objective of this proposal was to expand MSFC in-house capabilities by developing innovative 3D dynamic displays, tools, and programs to simulate gaseous configurations, interactions, and dynamics through the rendering of 3D gaseous volumes into 2D images. Having these line-of-sight images allows the backward interpretation of observations to obtain the 3D structure of the phenomena. The main intention of the research proposed is to develop pseudo-imaging techniques of soft x-ray emission to compare with observations in order to investigate the structure of the coronal magnetic field by analyzing the field line and emission characteristics. Data analysis techniques were applied to the MSFC vector magnetograms and the Kitt Peak National Observatory (KPNO) longitudinal magnetograms to characterize the spatial and temporal changes of magnetic and electric current systems within active regions.

Background

Since launch, the Japanese solar Yohkoh satellite has been revealing many new aspects of solar coronal physics—coronal structures and dynamics, gigantic arcades formations, cusp-shaped flares, soft x-ray jets, microflares, single-loop flares, and loop-loop interactions. MSFC was the management center for the soft x-ray telescope (SXT) built by Lockheed for the Institute of Space and Aeronautical Sciences (ISAS) in Japan. MSFC involvement in solar x-rays and magnetic fields has been extensive including ATM's solar x-ray telescope S–056, MSFC's solar vector magnetograph, the MSFC and Stanford x-ray telescope rocket program, SXI, and Solar-B. This proposal has extended this effort into developing unique analysis tools for image display.

Approach

Software tools were developed to display pseudo x-ray images given field line data, characteristic temperatures, and emission measures. The derived images were compared with observations to determine the foot points, temperature, and densities. The study used existing codes for potential and force-free fields, temperature, and emission measures. Its development was restricted in this proposal to computer efficient integration and display software that is compatible for comparison with observations (e.g., Yohkoh SXT comparison). Having such software has provided SSL scientists with a unique ability to compete for NASA's Solar/Space Science programs due to its relevancy to NASA's Space Physics Program. This analysis is critical in determining both the magnetic fields, which provides the structure for solar active phenomena, and the electric currents, which provide the free energy for the dynamics of these phenomena and their associated influence on solar terrestrial phenomena. This program has a direct relationship to NASA's projects and involvement (e.g., HESI, Yohkoh, SOHO, TRACE, and advanced solar missions such as Solar-B and Solar Lite) in which the interpretation of x-ray and magnetic field data play a critical role in meeting the scientific objectives.

The development process was as independent of specific models as possible to allow for many

coronal models in the final version. The crucial development here was to provide an efficient computer algorithm that renders a 3D volume into a 2D image with adequate quality compatible for analysis and comparison with observations (e.g., SXT/Yohkoh). The code provides a systematic comparison between observed coronal flux tubes and models, and between coronal flux tubes and their foot point, i.e., the corresponding photospheric features. Using existing codes and scaling laws to determine the coronal emission measures and temperatures, and an instrument response code, one can determine theoretically the observed emission characteristics for each volume cell. Given this and some magnetic field configuration, the problem is one of integrating along the line of sight and displaying the resulting image. This problem is the one addressed and solved within the proposal.

Accomplishments

A set of theoretical models have been programmed to simulate the 3D coronal loop structures and allow images of these loops to be rendered. I have presented some initial results at the Workshop on Measurements and Analyses of 3D Solar Magnetic Fields (Scientific Committee on Solar-Terrestrial

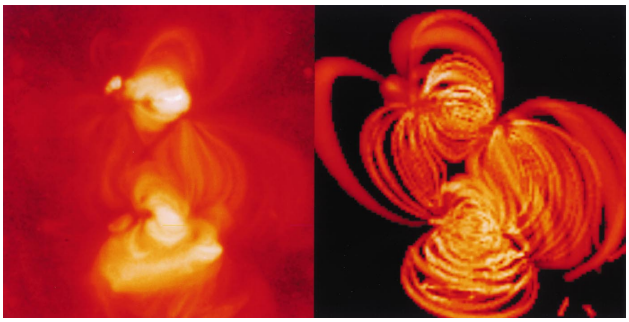

FIGURE 57.—A comparison of a soft x-ray image from the Japanese/American solar instrument SXT/ Yohkoh (left) with a set of synthesized coronal loops (right) is shown. The synthesized image was produced under the CDDF project. Initial comparison of the results is promising in that the overall morphology of the images is similar. As more detailed modeling is included, the important physical parameters of the coronal plasma will be established. The views shown here are a low-resolution version of the original digital display.

(SCOSTEP) meeting) and have a paper accepted to Solar Physics entitled, "Rendering Three Dimensional Solar Coronal Structures." An example of the research is shown in figure 57.

The software ALIAS/WAVEFRONT purchased ($41k, including training) under the project has been installed on the IPS/EADS II computer system since March 1996. Training sessions by 3Space Productions on the software were attended. One college student and two high school students have participated in the program. Nickolas Lineback, from Lee High School, Huntsville, AL, as part of the MSFC Student Volunteer Service Program (SVSP), worked with me on the project in the Spring of 1996. Munjal Thaker, from Bob Jones High School, Madison, AL, another SVSP, worked in the Winter/Spring of 1997. Zine Smith, Ouachita Baptist University, Arkadelphia, AR, under the NASA Academy, conducted his research in the summer of 1997 under the CDDF. An augmentation of the University Affairs funding by the CDDF allowed him to participate. We were able to create a script to simulate a solar surface fly-over of coronal loops. Coming from this research under this project, a response to a NRA proposal was submitted in August 1996. The proposal is entitled, "Analysis of Coronal Magnetic Structures via 3D Imaging/Rendering Techniques" with Dr. David Alexander (Lockheed-Martin Space and Astrophysics Laboratory) as co-PI. NASA Headquarters Science Director for the Solar-Earth connection. This proposal was not successful and will be resubmitted this year as part of the SoHO Guess Investigators Program. At the present time there are three proposals that have been submitted which depend on the work produced on this CDDF (see list below). An additional software support contract ($2k/PRISM support contract) was requested. The Director of the Space Environmental Laboratory (NOAA) has been given a preview of the work being done under the project and he has heartily supported our efforts.

Since the computer images generated under this research, once constructed, can be viewed from any direction, they have provided the impetus for a major proposal in response to the SMEX AO to

obtain coronal stereo pairs. This work played a major role in the preparation of the proposal which, it if is successful, will provide unique observations that will allow fully 3D reconstruction of the corona and the rendering scheme will play a major role in the mission design and data analysis.

The BATSE group has also made use of the software as a center side resource.

No significant problems arose. The work progressed smoothly and to a successful conclusion as seen in published papers listed in Publications.

Planned Future Work

Several proposals using the software and analysis developed under the CDDF program were submitted and will provide support for future work.

- "Stereo X-Ray Coronal Imager," NASA AO–97–OSS–03, PI: John Davis/ES82, Cost: $97.M
- "X-Ray/EUV Planning Studies and Development of Stereoscopic Visualization and Analysis Techniques for Future Solar Stereo Missions," NASA AO–97–OSS–08, PI: P.C. Liewer, JPL, Cost: $265.7k.
- "Sunspots and Coronal Heating: Flutes, Anemones, and Bifurcations," NASA AO–97–OSS–08, PI: N. Hurlbert/Lockheed-Martin Solar and Astrophysics Laboratory, Cost: $200k.

Movies of a solar fly-by were produced and are on the SSL home pages as a digital move (http://science.msfc.nasa.gov).

Publications

"Rendering Three Dimensional Solar Coronal Structures," Solar Physics, 1997, August.

"Comments on Solar Stereoscopic Missions for the Analysis of Coronal Plasma Structures," Solar Physics, 1997, submitted—under revision.

"Analysis of Active Region via 3D Rendering Techniques," with D. Alexander, PASP Conference Proceeding, 1998, in press.

Funding Summary ($k)

	FY96	FY97	Total
Authorized:	43	0	43
Obligated:	43	0	43

Zero funding level balance.

Status of Investigation

- Project approved—October 23, 1995
- Project completed—September 31, 1997